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Science & Applications of Space-based Cold Regions Observations

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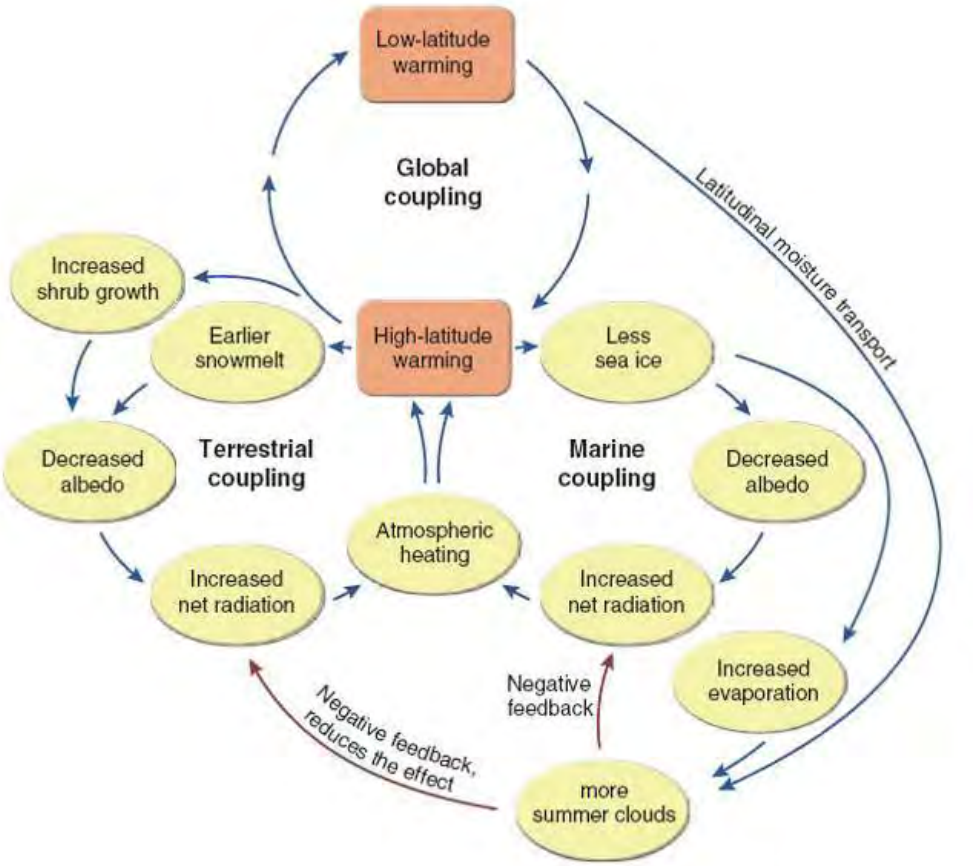
Snow, climate and water cycle

Conceptual diagram on the connectivity of the positive ice/snow albedo feedback, terrestrial snow and vegetation feedbacks and the negative cloud/radiation feedback (From UNEP, 2007).



Problems of ground-based observations

- **Sparseness of hydrological and meteorological observation networks**
  - Automatic observation networks replacing manual systems provide data from fewer locations (even though temporal frequency has improved in some cases)
  - Northern Eurasia: decrease of observations due to political/economical changes
  - Areal parameters most urgently needed for climate, hydrological and meterorological models, but they are typically difficult to observe:
    - Regional values of SWE
    - Fraction of Snow Covered Area (SCA) or binary snow information at high resolution (e.g. during spring in regions of seasonal snow cover)
- **Other relevant networks often even more sparser**
  - e.g. greenhouse gas monitoring

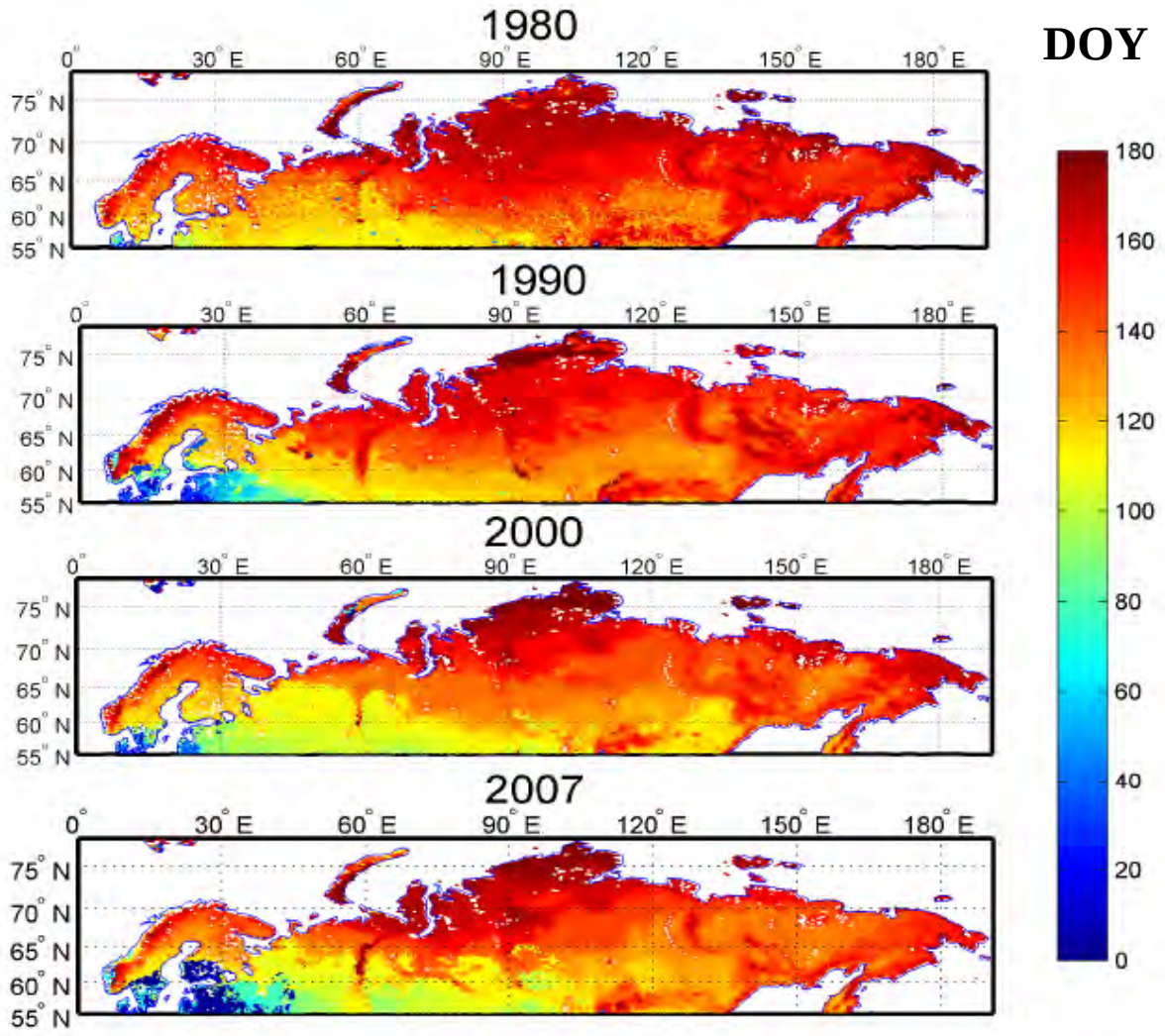
Example on global ground-based observing networks

Climate trends and validation of GCMs: Relation to snow cover

- **Snow cover parameters important climate change indicators:**
  - Lenght of snow season
  - Snow melt
  - Snow climatology (e.g. maximum SWE)
- **Time-series of snow information for validation of GCMs and climate (trend) projections**
  - Requires statistical information for long time-series ~30 years (statistics of satellite data retrivals should be compared with corresponding statistics of climate model simulations)
  - Key question: how reliable are the models simulations and future projections if snow cover is unreliably simulated

Snow melt date for ~30 years in northern Eurasia from space-borne microwave radiometer data

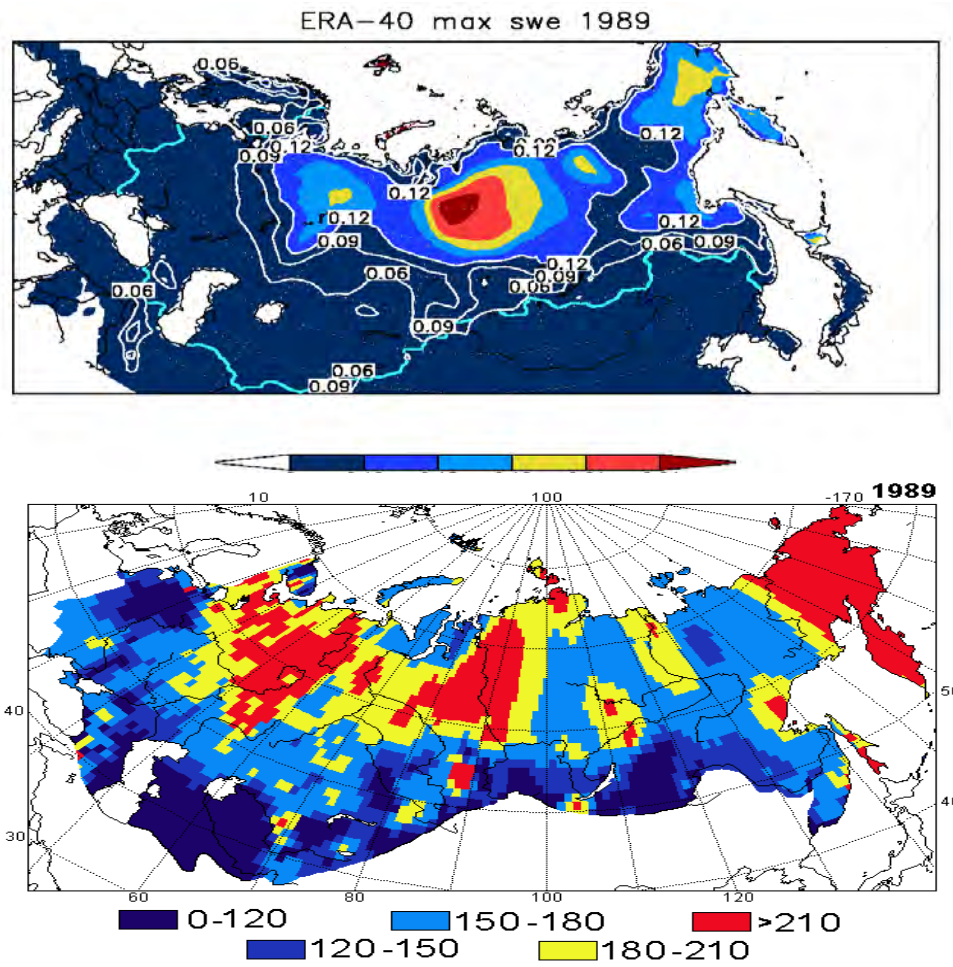
- Calibration here against ground-based observations at ~200 stations
- Some additional validation and calibration of melt detection algorithms can be carried out using e.g. optical data (cloud cover being a major obstacle)
- **CoReH20** mission would provide a major validation tool



The color code is the number of the melt date since January 1.

Deficits of re-analysis data and ground data interpolation

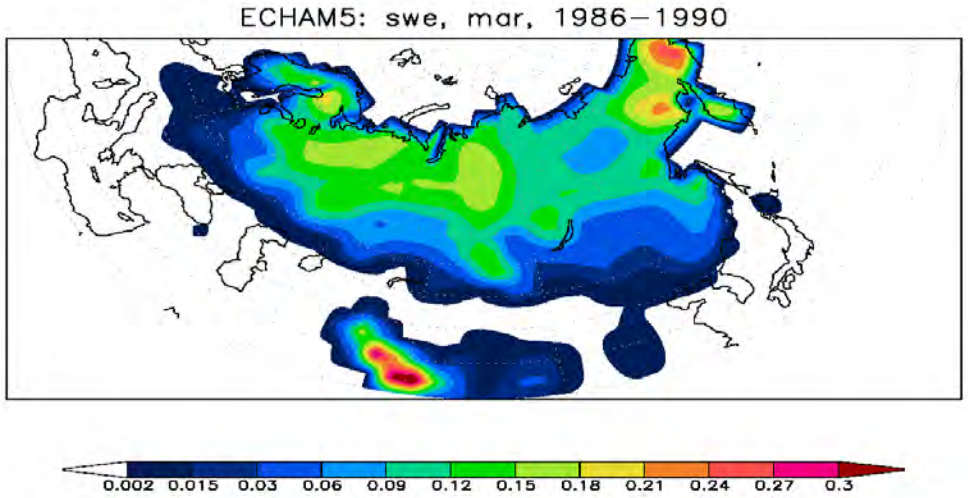
- ERA-40 re-analysis data of ECMWF:
  - Maximum SWE in 1989



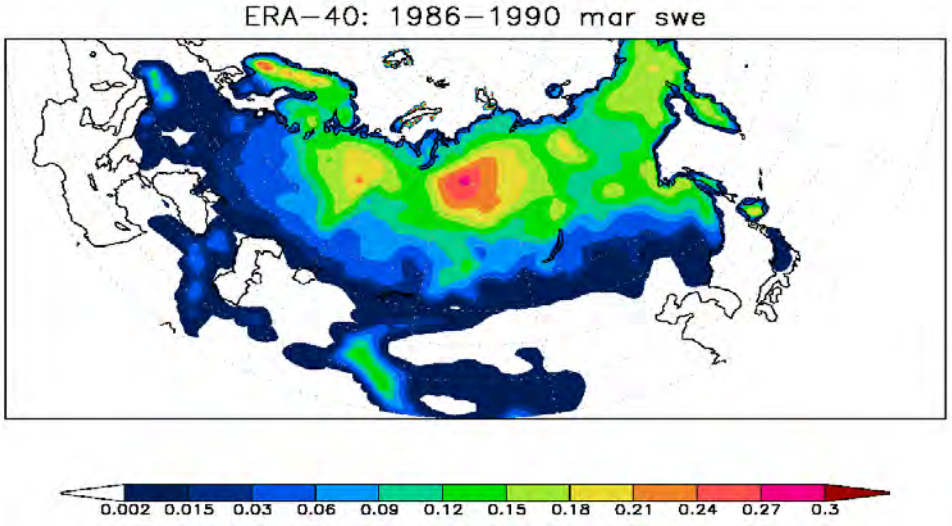
- Corresponding INTAS-SCCONE Russian ground based observations (SWE from 210 snow courses around northern Eurasia)

Deficits of climate modeling

ECHAM-5 GCM prediction

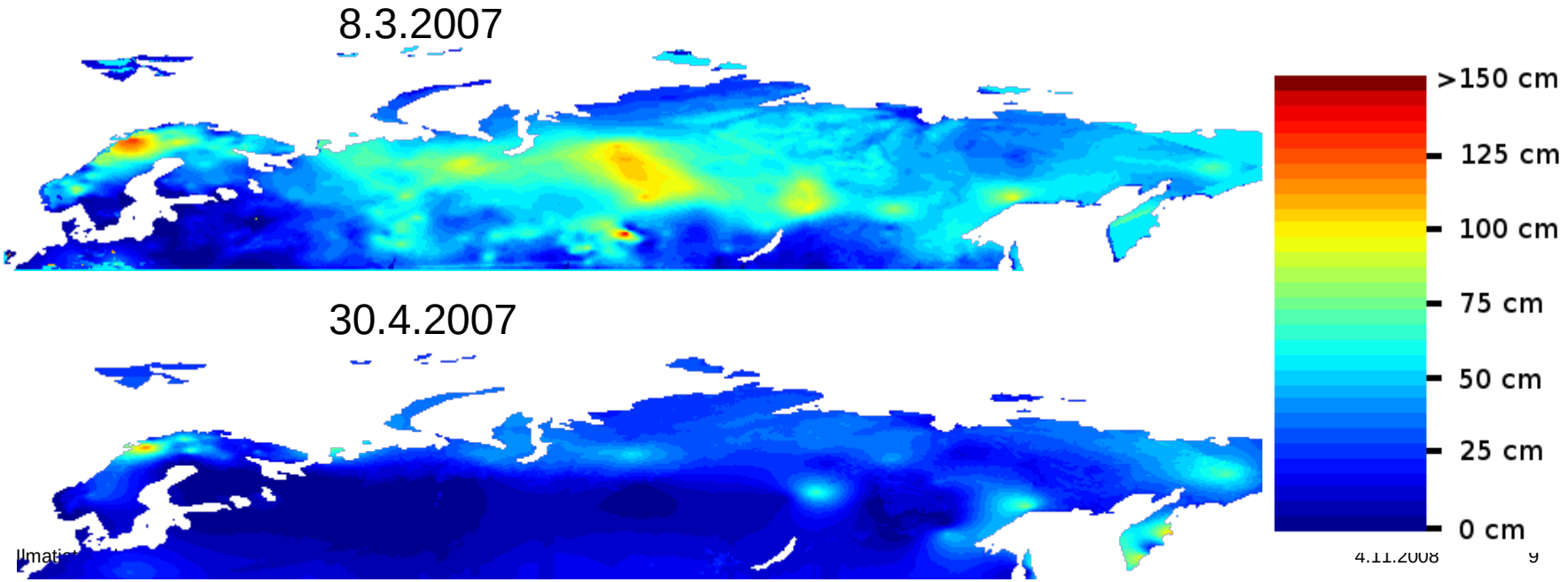


ERA-40 reanalysis data of ECMWF



Current ESA GMES PolarView Service of FMI: Northern Eurasian Snow Monitoring

- Snow Water Equivalent and Snow Depth by assimilating AMSR-E microwave radiometer and synoptic weather station data
- Currently validation against snow courses (~210 in Russia with length of some kilometers each)
- **CoReH20** would again provide data for validation and further development of algorithms

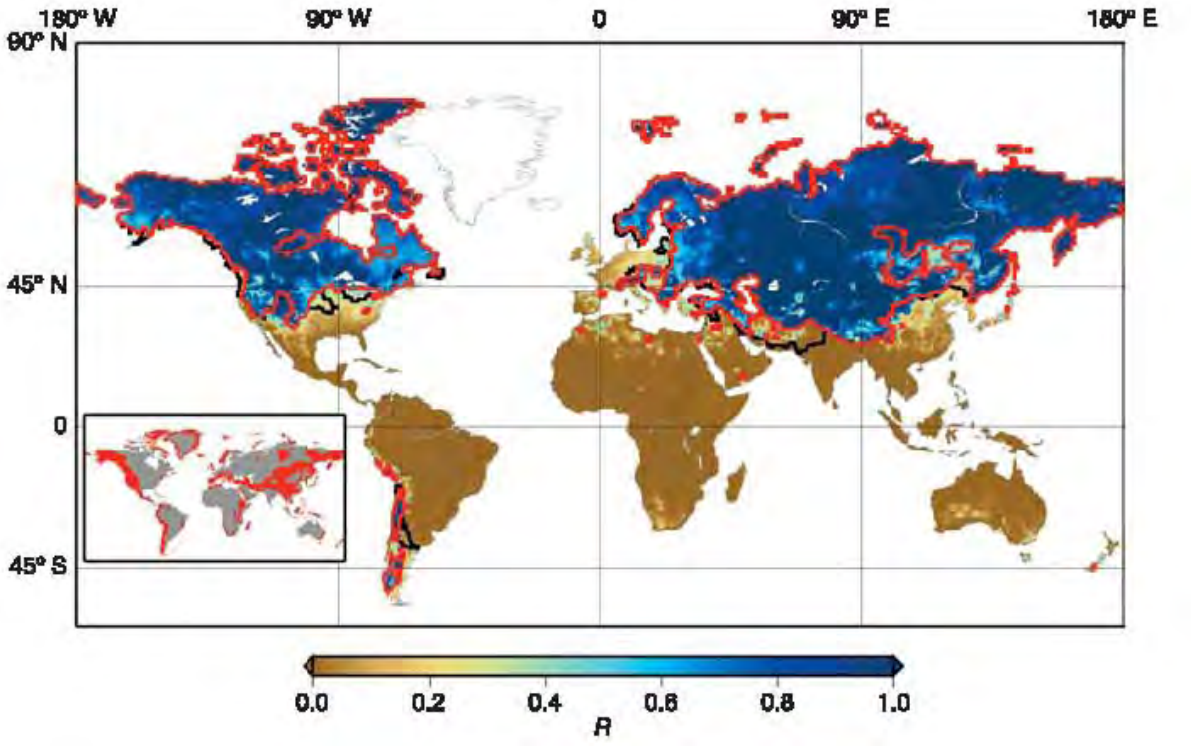


Applications in hydrology and meteorology

- **Water cycle:**
  - Hydro-power production: use of SAR-derived snow cover information as input to hydrological models even operational in several countries
  - Flooding (flood forecasting)
  - Availability of water resources
- **Meteorology**
  - Snow cover currently poorly represented (interpolation of ground data inadequate especially at high latitudes)
  - Dominates the surface albedo
  - Development of mesoscale models requires information on snow cover with higher spatial reslotion and down sclaling of coarse resolution data => need of new insruments such as CoReH20

Significance of snow information for runoff

- **Accumulated annual snowfall divided by annual runoff (colour scaled between 0 and 1). Red lines: streamflow is snowmelt-dominated, no adequate reservoir storage capacity to buffer shifts in the seasonal hydrograph.**
- **Black lines: additional areas where water availability is dominantly influenced by snowmelt**
- **Inset: regions of the globe that have complex topography. (From Barnett et al., 2005).**

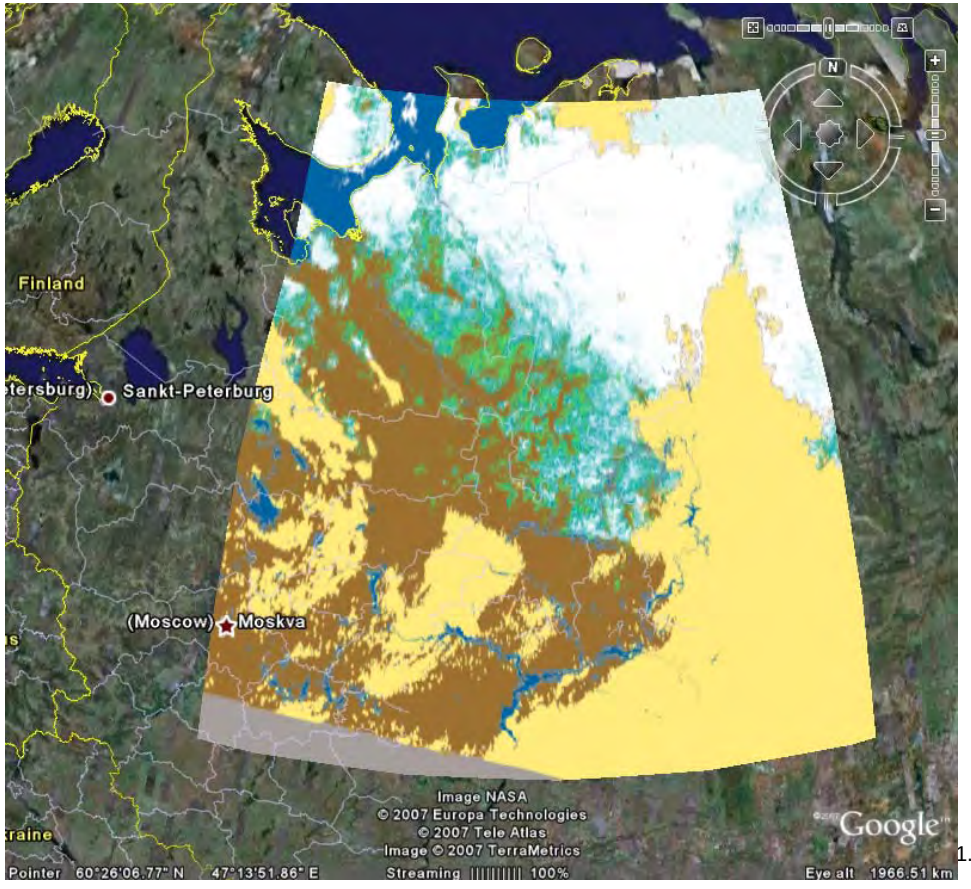


Examples of snow cover information at high resolution

- drawback: only small areas are currently operationally covered with C-band SAR system; clouds in case of optical data retrievals

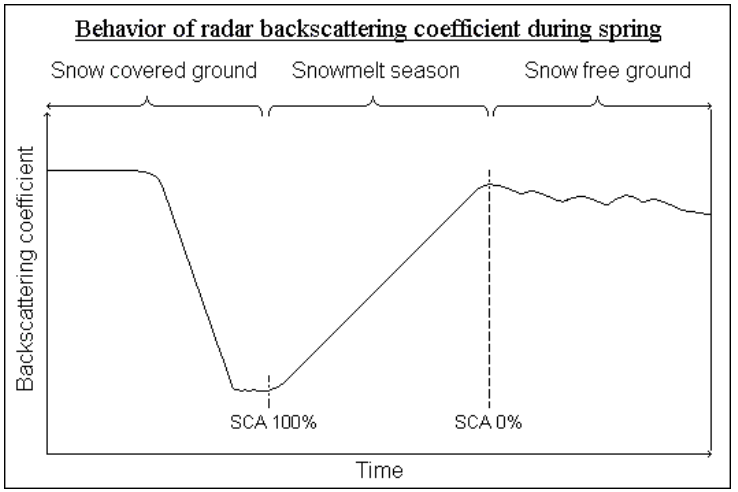
Snow cover at Norwegian mountains based on combined Envisat ASAR and Modis data

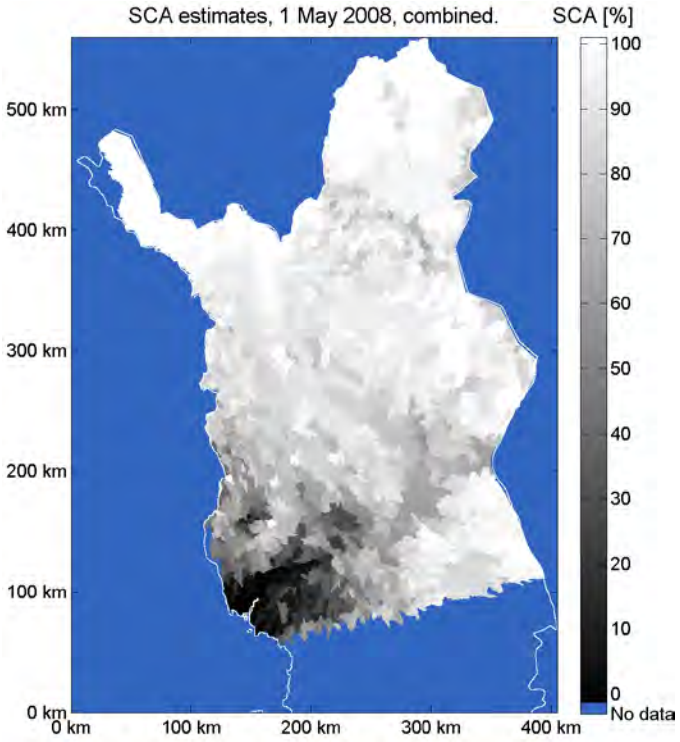
Modis data-based fractional snow-covered area



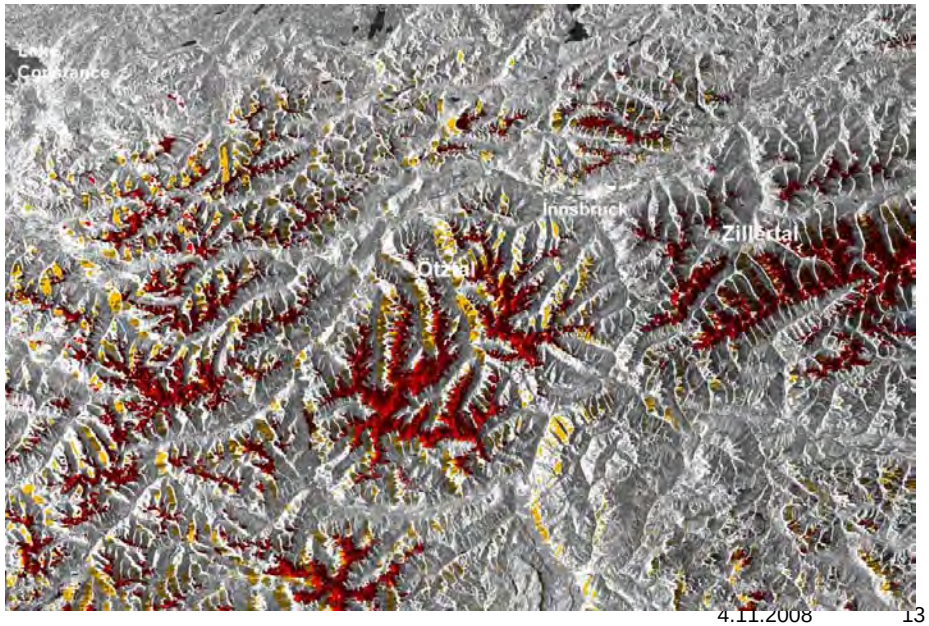
Example on application development for SAR: SCA for hydrological monitoring and forecasting

Radarsat-1 based
fraction of snow-covered area (SCA)
during the melting period





Envisat ASAR-based snow extent in Alps

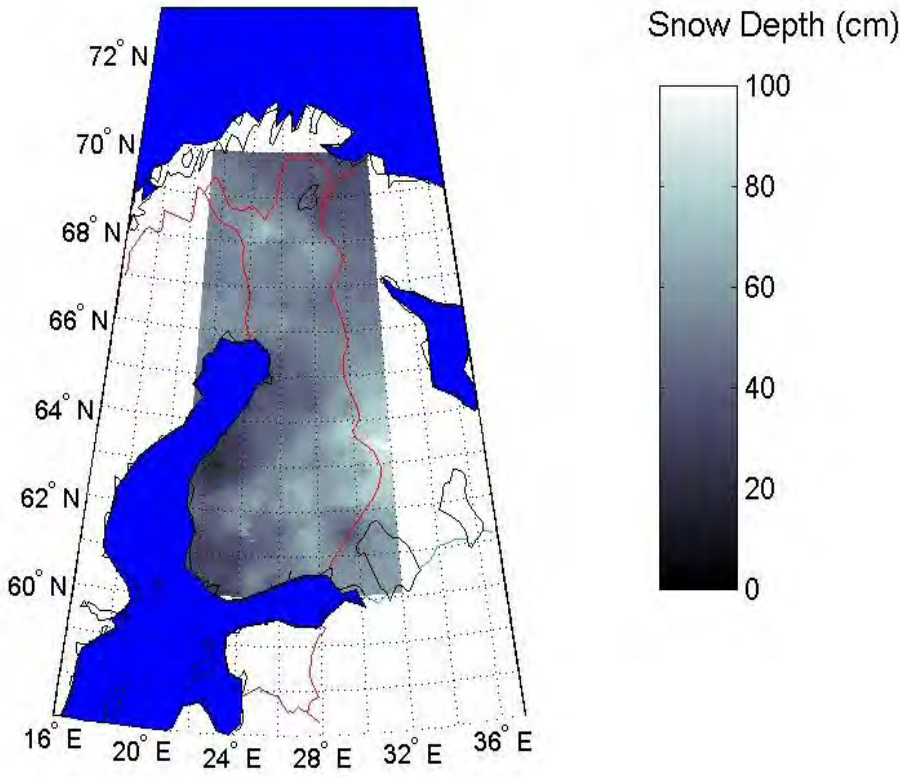


Snow water equivalent (SWE) and snow depth (SD) estimates from satellite microwave radiometer data

Technology: assimilation of satellite data with in situ observations (weather and hydrological stations)

Applications/end-users: hydrological models (e.g. floods), climate change studies, hydropower industry, numerical weather prediction, transportation

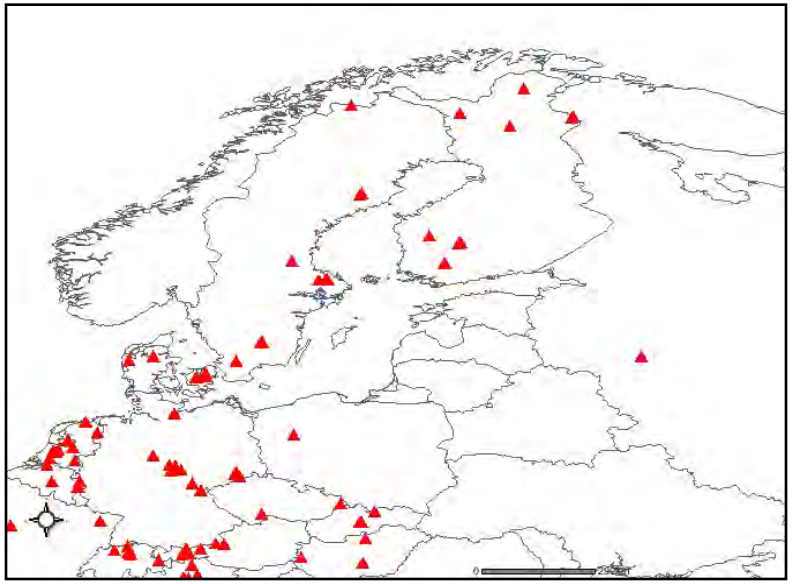
AMSR-derived snow depth for 2 Feb. 2004



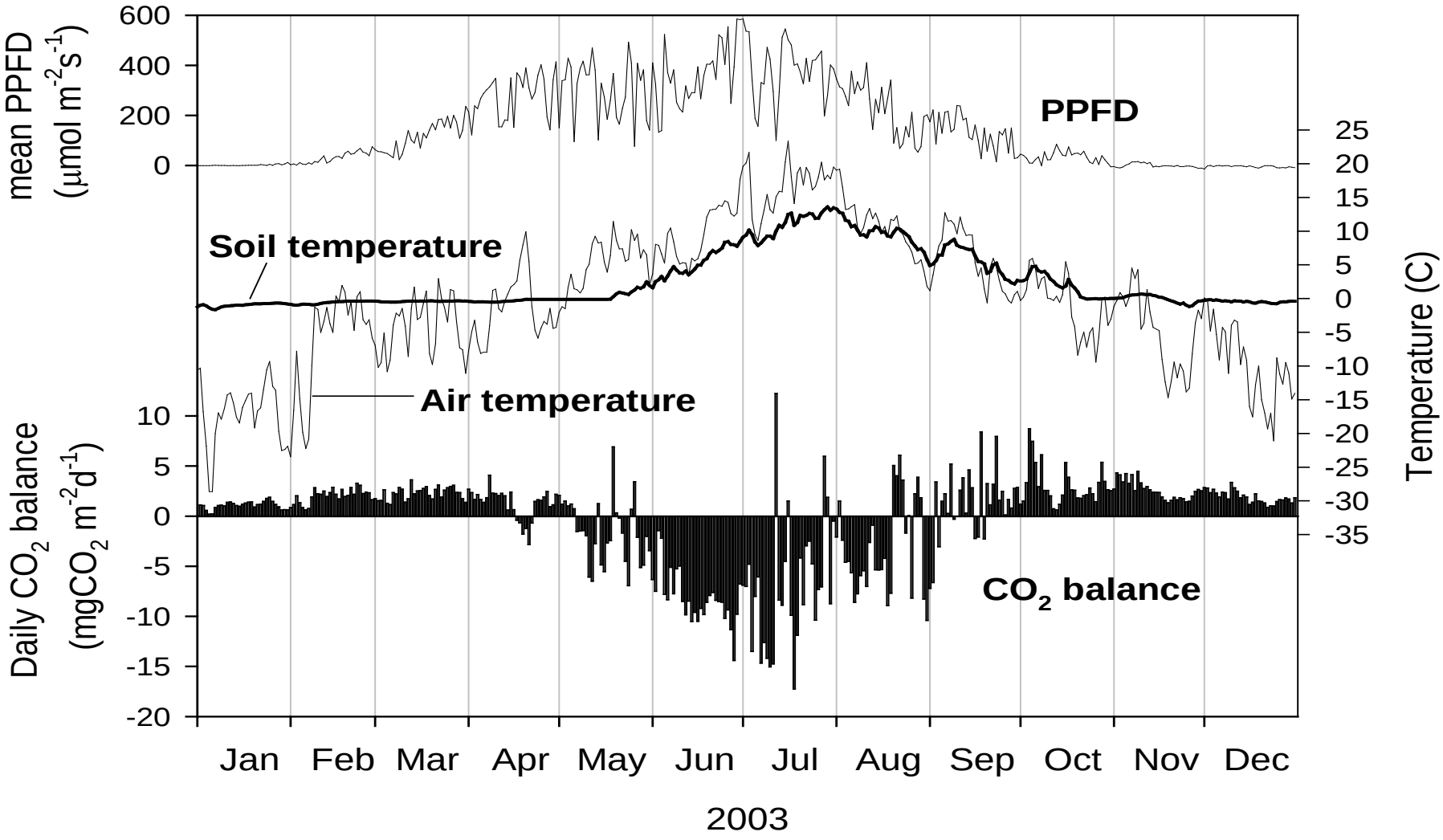
Carbon balance at high latitudes: Relation to snow cover

- **CO2 sinks and sources in boreal forests related to melt of snow and freezing of soil**
  - Annual balance in forested areas can be positive or negative depending of spring and autumn weather conditions
  - Combination of Earth System Models, remote sensing data retrievals and in situ flux observations can be potentially applied to map sink and sources
- **CH4 releases on wetlands dependent on the extent of permafrost**
- **Again sparseness of ground-based networks is a problem**

  e.g. European FLUXNET network:



Daily annual CO_2 balance at a spruce forest site

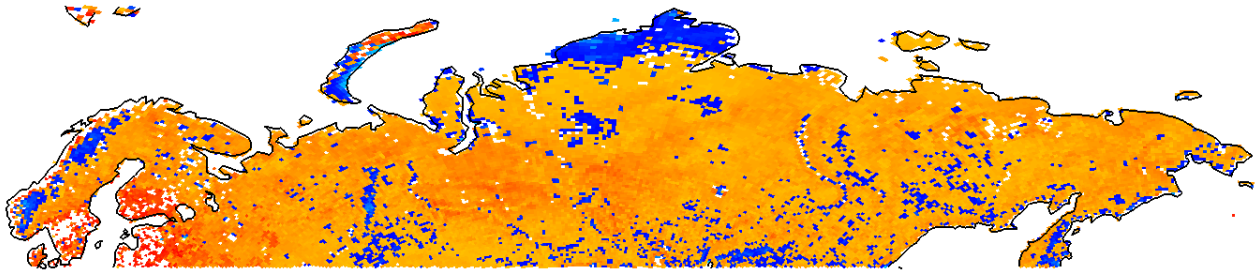


CH2 and CH4 flux observations available only for sparse networks

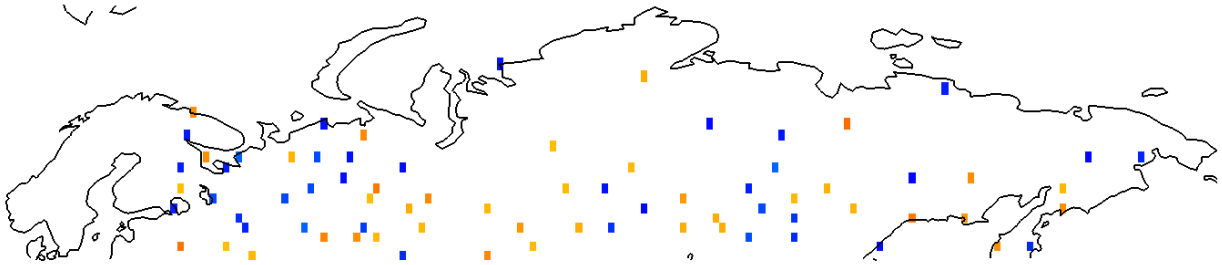
Estimated decadal trend for snow melt date

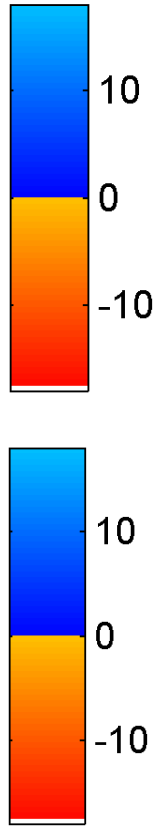
- Snow melt date estimates validated against ground-based observations
  - Trend estimated from the evolution of yearly snow melt (clearance) date
- Realistic values for off-coastal areas (mountains?)

Satellite data-derived trend (from 1978-2007)

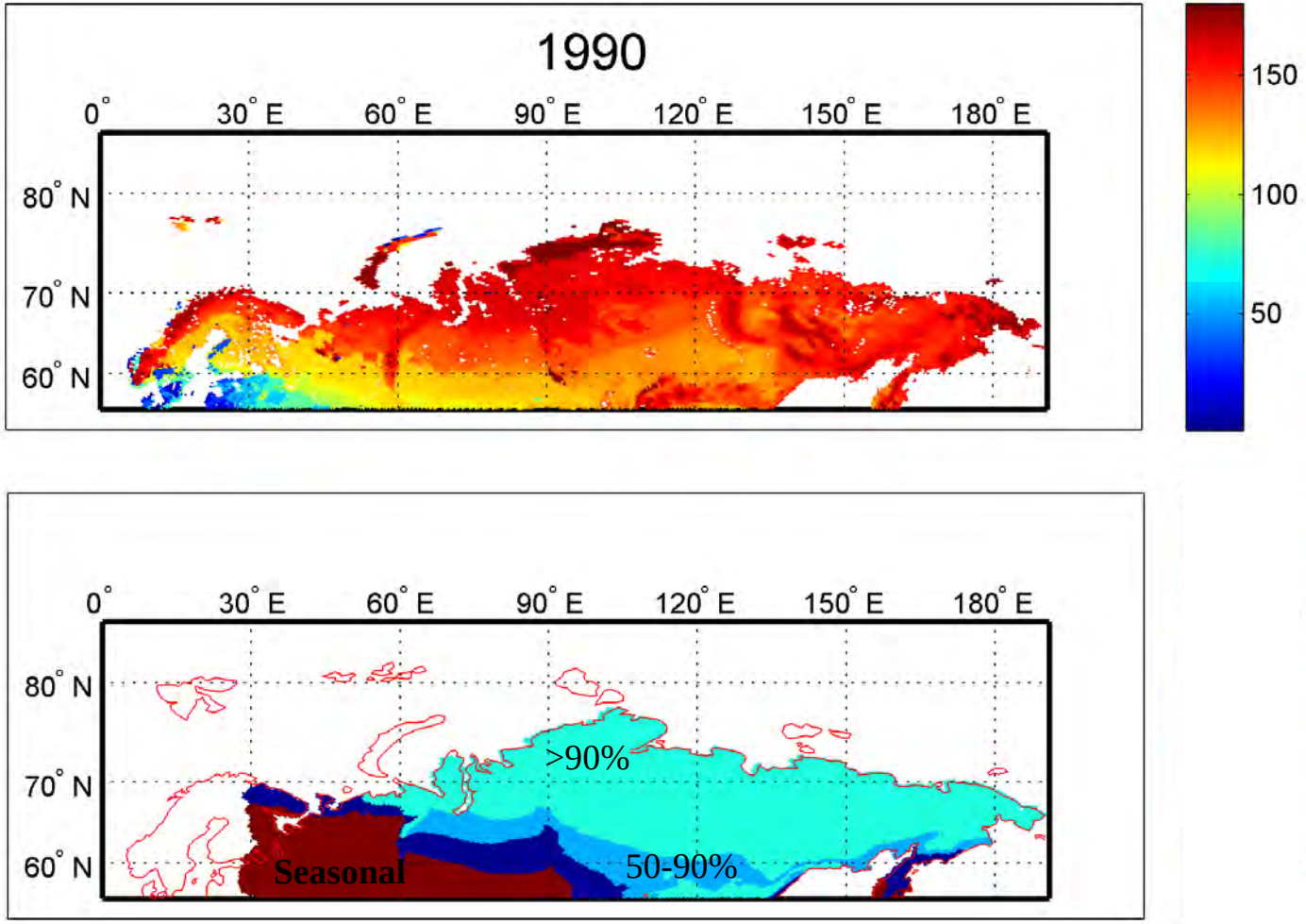


Trends in point-wise in situ observations (from 1978-2001)





Comparison of day-of-snow-melt with permafrost extent around 1980's (I)



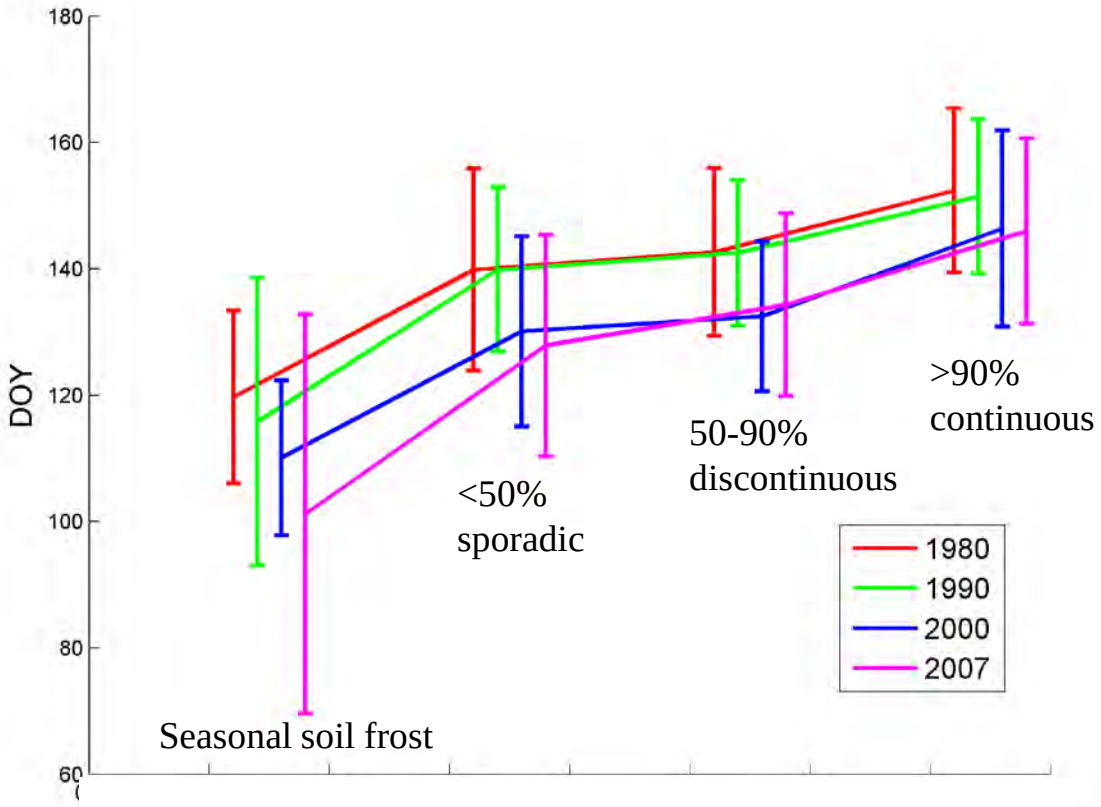
Comparison of radiometer data-derived day-of-snow-melt with permafrost extent around 1980's (II)

- Y-axis:

  EO data-derived day-of-snow-melt; mean values and standard deviation bars

- X-axis:

  Permafrost status in around 1980's from Russian reference map



Permafrost class in 1980's

Need of new observations

- **Current microwave systems lack either:**
  - High spatial resolution (microwave radiometers) or
  - Optimum frequency (C-band SAR not sensitive to SWE)
- **Downscaling techniques of coarse resolution data needed**
  - Meteorology: due to emerging mesoscale models
- **Improvement of hydrological and meteorological models**
  - Small scale features in the variation of SWE
- **Inaccuracy of SWE information**
  - Hydrology: SWE poorly known paramater (at regions of seasonal snow cover SWE largest cause of inaccurcy in run-off predictions)
  - Representation of snow realistically in climate models (regional climate models)

⇒ **Missions such as CoReH20 would provide a significant improvement concerning all these issues**